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ESTIMATION OF REFERENCE EVAPOTRANSPIRION USING A USER FRIENDLY DECISION SUPPORT SYSTEM: DSS_ET IN WESTERN UNDULATING ZONE OF ODISHA

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ABSTRACT

Reference evapotranspiration (ET_0) is an important agro meteorological parameter for climatological and hydrological studies, as well as irrigation planning and management. Due to wide application of evapotranspiration (ET) data, a number of indirect methods for estimation of Reference ET have been developed. Therefore, it becomes impractical for many users to select the best ET_0 estimation method for the available data and climatic condition. To overcome this problem, a decision support system (DSS_ET) was developed which supports 22 ET_0 estimation methods with varied options for calculation of various intermediate parameters, generalized data input format with copy–paste option from spreadsheet applications, visualize/check input data and results, features to estimate missing data, and user-friendly graphical user interface (GUI) that enhances its applicability as a handy research and teaching tool. The objective of the study is estimation of Reference evapotranspiration in the zone of Western Undulating Zone Odisha, using weather data of the respective locality and screening of methods to estimate reference crop evapotranspiration close to FAO-56 Penman Monteith method. For this zone, the highest ET_0 values was found to be 10.61 mm/d for FAO-24 Penman(c=1) method followed by Businger-van Bavel (10.41 mm/d) and FAO-PPP-17-Penman (9.98 mm/d) in the month of May, whereas, lowest ET_0 value was found in the month of December (2.95 mm/d) for the Priestly-Taylor method followed by 1982 Kimberly-Penman method (2.97 mm/d). For this zone, correction factor for Penman-Monteith, Hargreaves and 1982 Kimberly-Penman methods approaches to one. The FAO-24 Penman (c=1), Businger-van Bavel and Priestly-Taylor methods give more diversion from FAO-56 Penman-Monteith method.

KEYWORDS: DSS_ET, Reference Evapotranspiration, FAO Penman Monteith, Businger-van Bavel and Priestly-Taylor

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INTRODUCTION

Reliable estimation of evapotranspiration is of great importance for the computation of irrigation water requirements, water resource management and determination of water budget especially under arid conditions where water resources are scare and fresh water is a limited resource.Water plays a vital role for every living being. Water is and will become scarce natural resource in the near future. A clear understanding of the water balance is essential for exploring water saving measures. Due to economic and environmental constraints on new water resources developments, and increasing municipal and industrial needs, agriculture's share of water use is likely to go down day by day. In agriculture, most of the water is lost due to evapotranspiration by the canopy cover of the

plant and surface evaporation. It is the combination of soil evaporation and crop transpiration process. About 70% of the water loss from the earth's surface occurs as evaporation (Almhab and Busu, 2008). Thus, accurate estimation of evapotranspiration is very important for studies, such as hydrologic water balance, irrigation system design and management, water resources planning and management, etc. The rate of evapotranspiration from an extensive surface of 8-15 cm tall, green grass cover of uniform height actively growing, completely shading the ground and no shortage of water is called as the reference evapotranspiration (Doorenbos and Pruitt, 1977). Allen.et al., (1998) defined ET0 as "the evapotranspiration from a hypothetical reference crop with an assumed crop height of 0.12 m, a fixed surface resistance of 70 sm-1 and albedo of 0.23, closely resembling the evapotranspiration from an extensive surface of green grass of uniform height, actively growing, completely shading the ground and with adequate water". The evapotranspiration rate is normally expressed in millimetres per unit time (mm/day). Estimation of evapotranspiration requires number of parameters. Therefore, it becomes impractical for many users to select the best ET0 estimation method for the available data and climatic condition. To overcome this problem, Reddy (1999) developed a decision support system consisting of nine widely used ET0 estimation methods. This decision support system was further modified to include more ET0 estimation methods (Swarnakar and Raghuwanshi, 2000) and named as DSS_ET model.

Bandopadhyay et al., (2008), further improved this model. The DSS_ ET model can be used to identify the best ET0 method for different climatic conditions. It is developed in Microsoft Visual Basic 6.0. It consists of a model base for estimating ET0 by twenty-two different methods and ranking them and a user-friendly graphical interface. These available methods can be used for estimating daily and monthly ET_0 values for the time interval considered in this study. The aim of present study is to estimate the reference evapotranspiration by using the available methods and ranked them to find the best suited method

MATERIALS AND METHODS

Odisha lies at north latitude 17° 78' and 22° 73' and east longitude 81° 37' and 87° 53' with average elevation of 45 meters above MSL and a coast line of 480 km. It has a geographical area of 1, 55, 707 sq. km (4.87% of total area of India). Odisha is differentiated into ten different agro-climatic zones. The analysis was carried out on the basis of climatic data available at different agro-climatic stations. Thirty-three years (1981-2013) daily climatic data of minimum and maximum air temperature, mean relative humidity, average wind speed, solar radiation, and rainfall were collected from the website *http://global weather. tamu.edu/home/view/13292*.The Western Undulating Zone have two research station (Bhawanipatna) lies at Latitude (^{0}N) 19.9000 and Longitude (°E) 83.1700 with Hot and Moist climate and the mean annual rainfall (mm) is 1648mm.

Estimation of Reference Evapotranspiration

The methods given below are taken for estimation for ET_0 for present study estimated by using following methods,

- Standardized form of FAO-56 Penman-Monteith by ASCE 2005
- Penman Monteith Method (Monteith (1965), Allen (1986), Allen *et al*. 1989)
- Hargreaves Temperature Method
- Priestly-Taylor Radiation & Temperature Method

- Turc Radiation and Temperature Method
- 1972 Kimberly-Penman Method
- 1982 Kimberly-Penman Method
- CIMIS Penman method
- FAO-PPP-17 Penman (ET_0) method
- FAO-24 Penman (c=1) (ET_0) method [Doorenbos and Pruitt (1975, 1977)]
- Businger-van Bavel (ET_0) method

DSS_ET is a Decision Support System developed at IIT, Kharagpur for estimation of Reference evapotranspiration in daily basis. The DSS_ET model (Reddy, 1999) developed in Microsoft Visual Basic 6.0 is used in this present study to estimate reference evapotranspiration. By using the available daily climatological data, the daily reference evapotranspiration (ET_0) values were estimated for 33 years duration, using ten available methods.

Statistical Analysis

ET_0 estimates from all methods were compared by using simple error analysis and linear regression. For each location, the following parameters were calculated

- Standard Error Estimate (SEE)
- Root Mean Square Error (RMSE)
- Percentage Error Estimate (PE)
- Mean Bias Error (MBE)
- Coefficient of Determination (R^2)
- Regression Coefficient (b)
- Monthly Mean (mm/d)

The performance of a model is good when regression coefficient (b) is close to 1.0, $R^2 > 0.6$, RMSE < 0.6 mm d^{-1} and PE < 20%.

RESULTS AND DISCUSSIONS

ET_0 Comparison for Western Undulating Zone

The mean monthly ET_0 was estimated using all the methods and compared with the Penman-Monteith estimates. Out of all the 10 methods, the FAO-24 Penman(c=1) method yielded the highest mean ET_0 (6.574 mm/day). The Priestley-Taylor methods estimated the lowest mean ET_0 of 4.383 mm/day. The Penman-Monteith and Priestley-Taylor methods resulted in the minimum and maximum SEE and RMSE values respectively. Similarly the percentage error (PE) is found minimum and maximum for Hargreaves and FAO-24 Penman(c=1) method respectively. Priestley-Taylor and Hargreaves methods resulted the minimum and maximum mean bias error (MBE) values respectively (Table 1).

For this zone, the highest ET_0 values was found to be 10.61 mm/d for FAO-24 Penman(c=1) method followed by Businger-van Bavel (10.41 mm/d) and FAO-PPP-17-Penman (9.98 mm/d) in the month of May, whereas, lowest ET_0 value was found in the month of December (2.95 mm/d) for the Priestly-Taylor method followed by 1982 Kimberly-Penman method (2.97 mm/d).

Table 1: Statistical Summary of Monthly ET_0 Estimates for Western Undulating Zone

	ET_0 Methods									
Statistical Parameters	**PM**	**KP-82**	**KP-72**	**FAO-PPP-17-P**	**FAO-24-P(c=1)**	**HG**	**BvB**	**Turc**	**PT**	**CIMIS-Penman**
Mean (mm/d)	5.098	5.139	5.682	5.971	**6.574**	5.270	6.392	4.783	**4.383**	5.768
R^2	**0.994**	0.917	0.990	0.985	0.989	0.879	0.983	0.862	**0.566**	**0.994**
SEE(mm/d)	**0.199**	0.611	0.551	0.881	1.465	0.736	1.331	0.884	**1.598**	0.577
b	0.977	0.987	1.089	1.148	**1.257**	0.982	1.229	0.902	**0.793**	1.094
PE	2.18	1.39	9.01	14.55	**26.14**	**1.11**	22.64	8.23	15.92	10.67
MBE	-0.114	-0.073	0.469	0.758	1.362	**0.058**	1.179	-0.429	**-0.829**	0.556
RMSE(mm/d)	**0.198**	0.611	0.551	0.881	1.464	0.736	1.331	0.883	**1.598**	0.577

Ranking of ET_0 Estimation Methods

The PM method performed very well throughout for all the zones; hence, it was ranked as first form the zone. The PM equation includes vegetation leaf area effects on canopy resistance and vegetation height effects on the surface roughness parameter, which appears to significantly improve the accuracy of this method for estimating ET_0 over a wide variety of climates and locations. From the above study in the western undulating zone of Odisha. we arrived at the following ranking of different methods. Penman Monteith was ranked first among all the methods whereas Priestly-Taylor (PT) method was ranked as the least convincing method.

Table 2: Ranking of Different Methods for this Zone with Respect to FAO-56 PM Method

Station Name	PM	KP-82	KP-72	FAO-PPP-17-P	FAO-24 P (c=1)	HG	BvB	Turc	PT	CIMIS-Penman
western undulating zone	1	4	2	5	9	6	8	7	10	3

Correction Factor for Western Undulating Zone

For this zone, correction factor for Penman-Monteith, Hargreaves and 1982 Kimberly-Penman methods approaches to one. The FAO-24 Penman (c=1), Businger-van Bavel and Priestly-Taylor methods give more diversion from FAO-56 Penman-Monteith method. The correction factor for western undulating zone is shown in figure 1.

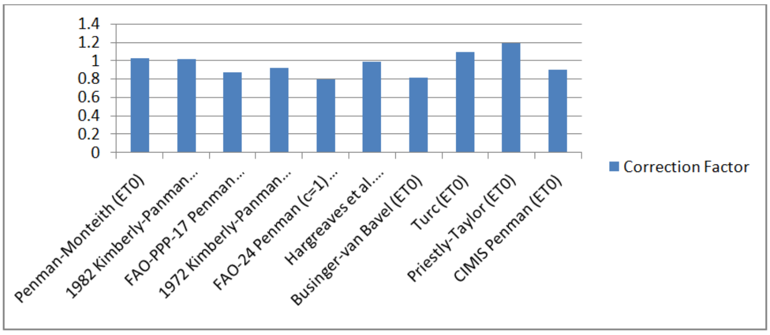

Figure 1: Correction Factor for Western Undulating Zone

CONCLUSIONS

In this study, the ET_0 was estimated from the available climatic data for North western agro-climatic zone of Odisha, India by all 11 applicable methods using DSS_ET software. The long term daily climatic data of minimum and maximum air temperature, mean relative humidity, wind speed, solar radiation and sunshine hours obtained from website were used to estimate reference evapotranspiration. By taking the standard FAO-56 Penman-Monteith method, other methods are statistically analyzed with different parameters of SEE, MBE, PE, RMSE, coefficient of determination and regression coefficient. Ranking of the 10 methods was done on the basis of SEE with respect to FAO-56 PM ET_0 to decide the best ET_0 estimation method. In addition, a correction factor to convert ET_0 estimates of different methods to the equivalent of the FAO-56 PM method was also determined for each method for the Western Undulating Zone zone of Odisha. Among the combination based methods, PM method gave ET_0 estimates closer to the standard FAO-56 PM method than other methods. After Penman-Monteith method, KP-72 method results better in the zone. Priestly Taylor and FAO-24 methods performed poorly for the ago-climatic zone. May month was found as the peak ET_0 month whereas the minimum ET_0 occurred during December and January for this zone. For this zone, correction factor for Penman-Monteith, Hargreaves and 1982 Kimberly-Penman methods approaches to one. The FAO-24 Penman (c=1), Businger-van Bavel and Priestly-Taylor methods give more diversion from FAO-56 Penman-Monteith method.

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